S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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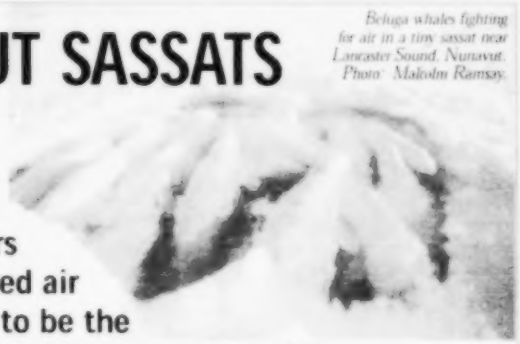
BREAKING THE ICE ABOUT SASSATS



Beluga whales fighting for air in a tiny sassat near Lancaster Sound, Nunavut. Photo: Malcolm Ramsay.

In the spring of 1999, a University of Saskatchewan biologist tracking polar bears on Lancaster Sound, north of Baffin Island, discovered a group of more than two dozen bears gathered around a cluster of swimming pool-sized air holes in the solid sea ice. The holes turned out to be the only lifelines for some 75 whales that had been trapped more than 30 kilometres from open water by a sudden advance in the ice edge.

Although the Inuit have long known about this unique polar phenomenon, which they call a sassat, the entrapment of whales in Arctic sea ice is rarely witnessed because the air holes are so difficult to spot — especially from the air. The events appear to take place in early spring, when whales enter areas of unconsolidated or loose pack ice in search of food. Because ice concentrations in these packs are already about 80 per cent, certain conditions can cause them to solidify or consolidate very quickly, leaving the whales stranded without sufficient breathing holes to reach the open ocean. Forced to enlarge existing holes and remain there until the ice breaks up, they become easy prey for polar bears and Greenland sharks.

Last fall, the University approached Environment Canada's Canadian Ice Service to help determine precisely when the Lancaster Sound sassat occurred and to identify the conditions that cause late season ice-edge surges. The collaboration is an important step toward understanding how frequently these events occur, and the mysterious relationships between ice-associated animals and sea ice conditions. By understanding these linkages, scientists hope to determine the potential repercussions of climate change on sea ice formation and animal populations. For example, if global warming causes sea ice to begin melting earlier and forming later, polar bears may have less time to forage for food, but might benefit from increased opportunities for sassats.

Satellite image showing how a rapid advance in the ice edge trapped the whales some 30 kilometres from open water.

Using satellite imagery collected for the operational ice forecasts they provide to the shipping industry, ice experts narrowed the date of the sassat down to three or four days in mid-April by monitoring changes in the ice edge. Additional meteorological information helped them pinpoint April 16 as the most likely date of the event, because that was when a high pressure system brought very cold temperatures and winds from the northeast, which pushed the unconsolidated pack ice up against the ice edge. They estimate that the ice advanced about 30 kilometres in less than 48 hours, and that the sassat lasted about 60 days.

As the first sassat studied by Canadian biologists, the Lancaster Sound event yielded some interesting information. Four bears tranquilized at the site proved heavier than the heaviest specimens ever measured in their age and sex classes in more than 10 years of study — proving that the bear exploit this phenomenon heavily and in a short period of time. The whales were also significantly affected, with a number badly injured or killed as a result of attacks suffered from below and above, as they surfaced to breathe. Although the whales represented less than one per cent of the local beluga population, the potential impact of several events each year could be significant. Of even greater concern is the fact that one of the whales involved was an endangered bowhead. Observations made at the site also offered the first evidence that Greenland sharks prey on live whales.

This spring, ice scientists have stepped up their monitoring of the ice edge and meteorological data to identify potential entrapment conditions — including calm conditions with very low temperatures, and storms that break up the ice edge, making it possible for it to re-consolidate later. They also plan to examine the conditions surrounding a similar incident near Grise Fiord, 100 kilometres north of Lancaster Sound, that also occurred in the spring of 1999. By using their knowledge of how, when and why sea ice forms to assist biologists in locating sassats for further study, Environment Canada's ice scientists are greatly improving our understanding of the biological significance of this little-known phenomenon. S&E

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KNOWLEDGE OF ALPINE WEATHER AT A PEAK

As hikers, skiers and pilots know from experience, alpine weather can be both extreme and unpredictable. For reasons that are still little understood, the topography of the world's mountainous regions can cause sudden, violent meteorological conditions — from gusting winds and clear air turbulence to hailstorms and torrential downpours. These conditions can trigger flash floods, landslides and avalanches, and pose hazardous in-flight conditions for aircraft.

To learn more about the mechanics behind these systems and to improve the understanding and prediction of alpine precipitation and flooding, more than 200 scientists from Canada, the United States, Britain, France, Germany, Austria, Italy, Switzerland and Slovenia spent 10 weeks in the European Alps last fall as part of the decade's largest and most sophisticated mountain weather experiment. Known as the Mesoscale Alpine Programme, it focused on weather systems that are 10 to 100 kilometres across — the ones that carry weather conditions you can feel, such as thunderstorms, hail and snow.

The Alps were chosen not only because they have more meteorological instrumentation than any other area of the world, but also because of the profound influence they have on regional weather. Most natural disasters in the Alps and the surrounding area are caused by alpine precipitation. Conditions peak in the fall, when warm air from the south absorbs moisture as it passes over the Mediterranean Sea and then cools suddenly over the mountains, sometimes dumping up to 30 centimetres of rain in a matter of minutes. Several sudden, major floods occur as a result each year.

Three regions were equipped with additional weather stations and measurement instruments and monitored by instrumented research aircraft: part of Germany's Rhine Valley and Austria's Wipptal Valley, and the Lago Maggiore region of Italy. A team of Environment Canada meteorologists were stationed at project headquarters in Innsbruck, Austria, to provide detailed hourly weather forecasts using an ultra-high-resolution software they have been developing over the past eight years.

The MC2 software, which was run on a Swiss supercomputer, collected data in real time from across the entire Alpine massif, from Lyon to Vienna. More than once a minute, the program updated information from thousands of points exactly three kilometres apart on a horizontal grid 1 000 kilometres square. Readings for each of these points were taken at 50 different atmospheric levels (twice that of a normal forecasting model), making it the first time such a fine mesh has been used to forecast conditions over such a large area.

A meteorologist taking readings at an Alpine weather station.

The detailed meteorological and topographical information collected using specialized instruments and research aircraft, coupled with the real time simulations carried out by the MC2, made it possible for the forecasters to detect even minute changes in cloud content and air movement, and forecast the strength of wind, precipitation and other weather parameters in the region to an unprecedented degree of accuracy. They were able to pinpoint the location of dangerous storms to within a few kilometres, and determine several hours in advance when they would start and stop. The state-of-the-art supercomputing technology used by the MC2, however, proved very expensive to use routinely over such a large area.

A second objective was to study and forecast gravity waves caused by changes in the density of the air. These highly localized oscillations often occur over mountainous terrain, and can cause extreme air turbulence for aircraft when they reach their peak amplitude and break, like ocean waves. Although the MC2 proved adept at calculating the strength of these oscillations, it had difficulty determining when they would break, although simulations over a smaller area on an ultra-fine one-kilometre grid improved the model's success rate significantly.

Scientists estimate that it will take about five years to analyze and interpret the more than 10 gigabytes of new forecast data collected daily over the course of the experiment, but their first early results will be presented at a meeting in Slovenia this June. This work will greatly improve the understanding and forecasting of hazardous alpine weather conditions and, as a result, the safety of people and property in mountainous regions around the world. S&E

SAVING CANADA'S ENDANGERED MUSSELS

Freshwater mussels are among the most endangered organisms in North America. Over the past century, researchers in the United States have reported severe declines in mussel diversity and abundance, but little was known about their status in Canada until recently. Now, a clear picture of what is happening to mussels in the lower Great Lakes drainage basin is beginning to emerge, and work is in progress to protect them.

North America has the greatest diversity of freshwater mussels in the world, with nearly 300 species. These invertebrates are particularly vulnerable to the effects of human activities because of a unique feature of their life cycle. Once their young have reached the larval stage, female mussels expel them into the water where they must attach to the gills or fins of a host fish to complete their development. This puts mussels at risk not only from environmental disturbances that affect them directly, such as habitat destruction, sedimentation and pollution, but also from those that affect their host fish.

The introduction of the zebra mussel to the Great Lakes in recent years has led to catastrophic consequences in an area that once boasted the most diverse and unique mussel fauna in Canada. Zebra mussels attach to the shells of native mussels, thereby interfering with their feeding, respiration, and burrowing. Populations of native mussels in Lake St. Clair, western Lake Erie, and the upper St. Lawrence River have been devastated.

In 1994, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) included invertebrates in its mandate for the first time, with molluscs one of the first two groups to be considered. This set the stage for researchers at Environment Canada's National Water Research Institute (NWRI) to launch a major effort to investigate the changes that have occurred in the composition of freshwater mussel communities in the lower Great Lakes drainage basin over the past century, and to identify species at risk.

Researchers gathered over 4 000 records taken between 1860 and 1996 on 40 species at 1 500 sites and entered them into a computerized database. The records came from a variety of sources, but primarily from six natural history museums in the Great Lakes area. Among the 200 investigators whose work was brought together for the first time were museum curators, graduate students, research scientists and 19th-century amateur naturalists.

When they analyzed the data, researchers discovered a pattern of species loss and changes in community composition throughout the basin, with displacement of many unique and ecologically fragile species by fewer pollution-tolerant species. The results of their work provided compelling evidence that the steady decline in mussel diversity already documented in the United States was also happening in Canada.

Researchers embarked on a risk-factor analysis to identify the species most at risk and to prepare a list of candidate species to be considered by COSEWIC for national status designation. A series of field studies conducted in various rivers in the research area in 1997-98 showed that the situation might not be as grim as originally thought. In the Grand River, which runs from Kitchener to Lake Erie, mussel populations appear to have rebounded, perhaps due to improvements in water quality resulting from better sewage treatment. The Sydenham River, in the southwesternmost tip of Ontario, was discovered to have the most diverse and intact mussel community of any of the rivers investigated, and probably of any in Canada, and is a major refuge for many rare species.

Identifying and measuring mussels on the shores of the Thames River in southwestern Ontario

In 1999, based on NWRI's status reports and recommendations, COSEWIC designated three mussel species as endangered. Now, with funding from several sources, work is in progress to develop recovery plans to protect and restore mussel communities in the Great Lakes basin. Once the disturbances threatening the health of mussel communities have been identified and resolved, species can be restored by stocking with lab-reared specimens, augmenting small populations with specimens from larger populations, and reintroducing mussels back into their restored historic habitat. S&E

Environment Canada scientist Peter Hennigar collecting mussels at Digby, Nova Scotia, as part of the Gulfwatch monitoring program.

SCIENTISTS PUT MUSSELS INTO MONITORING

The succulent blue mussels so many restaurants serve steamed with a wedge of lemon are being used by Environment Canada scientists in the Atlantic region to gauge levels of toxic chemical contaminants in the briny waters of the Gulf of Maine.

Mussels are an ideal indicator species not only because they are abundant and easy to collect, but also because they feed by pumping large volumes of water through their systems, exposing their tissue to contaminants in the process. Because mussels remain fairly stationary over the course of their lives, scientists can determine water quality in a specific area simply by analyzing the concentration of contaminants in the tissue of native mussels.

The Gulf of Maine is one of the most productive ecosystems in the world. Extending from Cape Sable, Nova Scotia, to Cape Cod, Massachusetts, and including the Bay of Fundy and Georges Bank, it supports a vast array of seaweeds, salt marsh grasses, phytoplanktons and marine animals, including many species of commercial importance. Unfortunately, human population growth and land development have dramatically increased the release of atmospheric and effluent pollution into the Gulf's coastal and estuarine environments over the past 50 years. Of particular concern are persistent toxic substances like polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, dioxins and furans, and trace metals, because they bioaccumulate in tissue and can magnify to biologically harmful levels in the food chain.

To protect the health of the species in the ecosystem, including the humans who consume its seafood, the Gulf of Maine Council on the Marine Environment established the transboundary Gulfwatch monitoring program. Since 1991, Environment Canada scientists and other members of the Canada/US Gulfwatch Monitoring Committee have headed to the shores of the Gulf each fall to hand-pick some 200 mussels at each sampling site — most located at the mouths of river watersheds and on coastal drainage systems. Samples are native mussels, but some clean transplants are also collected to evaluate the effects of short-term exposure to the Gulf waters. Five benchmark sites in Nova Scotia, New Brunswick, Maine, New Hampshire and Massachusetts are sampled annually, with the remaining 56 sites sampled once every three years on a rotating schedule.

Results have shown that concentrations of toxic organic contaminants and silver increase from north to south. Lead and chromium concentrations were elevated at sites within Massachusetts, New Hampshire and Maine. Other trace metals show a relatively uniform geographical distribution. Generally, contaminant concentrations were correlated with population density, latitude and distance from known contamination sources.

Very few sites have mussel tissue contaminant concentrations that exceed Canadian or American seafood human health tolerances; however, some have levels that require a more in-depth assessment of human health risk, and several exceed tissue concentrations considered harmful to birds and other wildlife. An examination of changes in data over time indicates that contamination levels at most benchmark sites are either decreasing or show no detectable change.

Government agencies in Canada and the United States use this information for a variety of purposes: to develop environmental management plans and policies, licensing requirements for industrial discharges, and pollution controls; to determine the safety of seafood; and to assess the effects of accidental spills and other specific events on water quality. Shellfish and fish aquaculturists use Gulfwatch data to find clean areas for harvesting and growing facilities.

Graph showing concentrations (2,3,7,8-TCDD TEQs) of PCBs and dioxins/furans found in mussel tissue at Gulf of Maine sites in 1996 and 1997.

Gulfwatch has recently begun collaborating with community-based environmental organizations to address local concerns about other toxic substances, including chemicals used by the aquaculture industry to kill parasites. Researchers hope that as public awareness about the impacts of toxic contamination grows, the use of these and other potentially harmful substances in this prolific ecosystem will decline. **S&E**

COOKING OIL AND CLIMATE CHANGE

That order of french fries with a lunchtime hotdog is just one of thousands of daily uses of cooking oil in Canada. What most people don't know, however, is that conventional methods for extracting oil from plant materials require enormous amounts of energy, which in turn produce significant greenhouse gas emissions. These methods also use large quantities of the solvent hexane, which, when released to the environment, degrades to produce greenhouse gases that contribute to climate change.

Canola flower
Photo: Canola Council of Canada

Scientists from Environment Canada's Environmental Technology Centre in Ottawa are working with CanAmera Foods and BC Research to increase the efficiency of the oil extraction process, and to reduce energy usage and greenhouse gas emissions. The three are undertaking a demonstration project to test the use of Environment Canada's patented Microwave-Assisted Process (MAP™) in extracting cooking oil from canola.

Canola was chosen not only because it is an integral part of Canada's economically important cooking oil industry, but also because current canola oil extraction methods are expensive and require large amounts of hexane. Hexane is not yet accounted for in Canada's greenhouse gas inventory, because its degradation in the environment is complex and not fully understood. It is known, however, that its initial degradation includes the rapid release to the atmosphere of carbon dioxide — a primary greenhouse gas.

The MAP™ technology requires less energy than conventional extraction methods because it uses microwaves to rapidly heat specific components of liquid and solid materials. It has already found extensive use in the laboratory to determine the nature and quantity of contaminants in drinking water samples, and to evaluate petroleum hydrocarbon contamination in plant material and soils. Since applying MAP™ to large-scale use in the food processing industry would require complex retrofitting and a significant investment in equipment, the technology will need to prove itself at least as efficient as current methods in order to be considered for broader applications in the future.

The demonstration phase of the project will involve producing around one tonne of canola oil per hour, but the ultimate goal will be to model the current production of 800 tonnes per day at CanAmera Foods' smallest facility, located in Hamilton, Ontario. In phase two of the project, testing will be done to substitute a liquefied gas, such as propane or butane, for hexane, in the hopes of limiting or eliminating hexane use in the canola oil production industry. Tests will also be performed to determine the feasibility of using MAP™ technology on other feedstock of importance to Canada, such as soya, rapeseed and flax.

Although the energy the food industry could save by using this new technology cannot be accurately determined until data are available on the level of application, a conservative estimate is that MAP™ would reduce energy requirements by at least 50 per cent. A number of private-sector companies in various parts of the world are interested in the outcome of the project, such as South Korea and China for use in rice-bran processing, Malaysia and Colombia for palm oil, Pakistan and India for rapeseed and soya, and various others for cocoa. If the test results are as expected, the technology could be transferred to other countries to help reduce their energy consumption and the greenhouse gas emissions that contribute to climate change. S&E

Canola flakes in hexane going through a processing system

ST. LAWRENCE HAS ITS UPS AND DOWNS

From the tiniest microorganisms at the bottom of the food chain to the giant ships that ply its channels, the waters of the St. Lawrence River are the lifeblood of an ecosystem that is a unique and integral part of Canada. When these water levels increase or decrease, because of natural or human influences, they cause a ripple effect on virtually every aspect of this ecosystem.

The water levels of the St. Lawrence have been monitored and recorded since the mid-1800s. These records show long-term cycles of peaks and valleys lasting 15 to 35 years, with a two-metre difference in average levels between the highest and lowest years. The river's lowest levels occurred in the 1930s and 1960s, and the trend is once again at the bottom of the curve. These levels could be severely affected by climate change, because higher temperatures would increase evaporation and longer periods of drought would decrease flow.

St. Lawrence Centre biologists taking water level measurements in a dried up marsh on the St. Lawrence River near Boucherville, Quebec, in August 1999. Under normal conditions, the water would come up to waist level.

To determine just how severe this effect could be, scientists at Environment Canada's St. Lawrence Centre and in the Meteorological Service of Canada are working with the Quebec government and universities to study the physical, chemical and biological components of the St. Lawrence River ecosystem. Their research involves everything from laboratory work to taking extensive samples of the river, shoreline and surrounding wetlands.

Although the sampling is still in its early stages, several trends are emerging. Extreme low water levels observed in 1999 resulted in a difference in the surface area of available habitats, causing an invasion of terrestrial, opportunistic plants into the dried-out wetlands. To the untrained eye, there may not have seemed much of a difference. For example, certain sections of riverbank seemed quite green, even when water levels were low. However, the question is of quality versus quantity. Are the plants in good variety, are they native plants, or is there an increase in the alien species and plants that don't provide much by way of food and cover for wildlife?

Animals, microorganisms, oxygen levels in the water, and the richness of the ecosystem itself are all affected by lower water levels. In the spring, for instance, less water is an advantage to duck populations because there is less risk of nests being flooded. But if the water stays low, there are no longer deep pools within reed beds where the ducks can feed, forcing them out of sheltered areas to find food. In the open water ducklings become more vulnerable to predators and disturbance by pleasure boaters.

The data collected through field sampling are fed into a numerical model of the St. Lawrence River that was developed by Environment Canada in cooperation with the National Institute for Scientific Research and other partners. The model, which concentrates on the region from Cornwall to Trois-Rivières, can be used to assess the impacts of different water-level scenarios in which the river physics and chemistry change. In essence, it uses physical aspects of the habitat, such as water depth, currents, waves and sediment, to predict the potential impact on the flora and fauna. A greater knowledge of the physics of the river also enables an informed response in the case of an oil spill.

Integrating biological information from field sampling with hydrological modelling will lead to a better understanding of the environmental challenges facing the St. Lawrence River ecosystem, and provide a framework for measures to protect this valued and integral part of Canada's natural landscape. S&E

Environmental quality guidelines for tissue residue protect wildlife consumers of aquatic life, such as the Common Loon.

HOW CLEAN IS CLEAN?

The presence of chemicals in the environment has become a fact of life in the modern, industrialized world. Many human activities — from driving vehicles to manufacturing paper — release potentially harmful pollutants into the world around us. To help protect the quality of our natural resources, Environment Canada scientists recommend specific limits for a variety of substances that, if exceeded, could impair the health and beneficial uses of our ecosystems.

Since 1987, the Department, working in collaboration with provinces and territories, has developed more than 500 national environmental quality guidelines for over 220 toxic substances of concern in Canada. Already in use in this country across all jurisdictions and recognized as a model for guidelines in Australia, southeast Asia, Mexico, Chile and other parts of the world, they were recently updated and released for the first time as a single compendium by the Canadian Council of Ministers of the Environment (CCME). The publication, entitled *1999 Canadian Environmental Quality Guidelines*, is the most comprehensive document of its type ever produced.

The development of environmental quality guidelines is carried out at Environment Canada by toxicologists, chemists and biologists who conduct experiments and comprehensive assessments of each substance. Working in cooperation with researchers from other governments, the private sector and academia, they evaluate the most up-to-date scientific information available from research around the globe, and use the results to determine the "no effect" levels. To make them truly national, the guidelines proposed are reviewed and approved by the federal, provincial and territorial environment ministries that report to the CCME Ministers.

A large and very complex part of this work is establishing scientific protocols for deriving the "no-effect" levels — that is, coming up with objective formulas for determining how much of a substance is too much in the environment. Toxic substances in the environment affect a wide variety of resource uses and, through these uses, numerous different receptors. Receptors affected by soil quality, for example, can include humans, livestock, various food crops and other vegetation, and a host of wildlife species ranging from prairie dogs to earthworms.

The numerous and varied ecosystems found in Canada have different beneficial uses, so the guidelines are developed to protect, maintain or restore these uses. For example, soil quality guidelines protect and sustain agricultural, residential, commercial and industrial land uses; whereas sediment quality guidelines protect aquatic life, and tissue residue guidelines protect wildlife.

Environmental quality guidelines are also used to promote sustainable agricultural practices.

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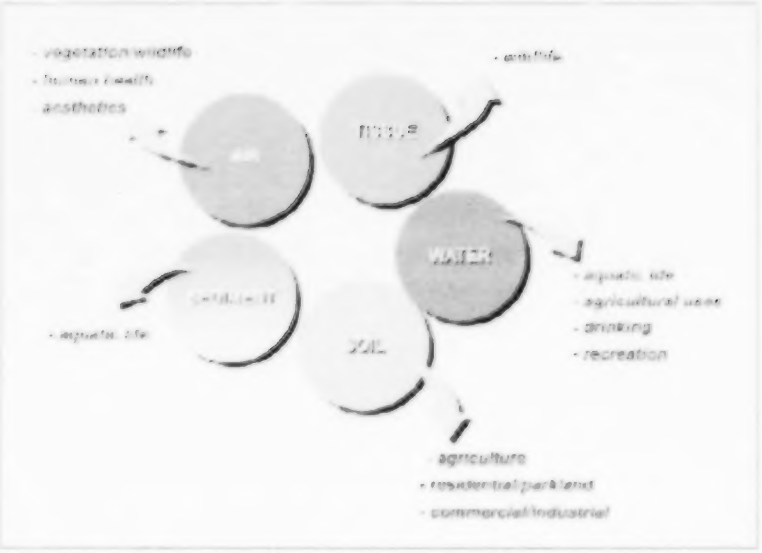
Environment Canada's science is critical in the creation of new knowledge and in answering questions regarding the use, behaviour, toxicological effects, major sources, concentrations of chemicals in the environment, their fate and persistence, and the influence of other environmental factors on their toxicity. This information, which is also included in the 1999 Guidelines, provides the scientific context and rationale for the numerical or narrative limits identified, and improves understanding of the impacts of exceeding them. Environment Canada scientists are also involved in determining which substances require environmental quality guidelines through their involvement in the development of the National Priority Substances List and other national activities, such as the development of Canada-wide standards.

As national benchmarks for the quality of our environment, these guidelines are used in a number of ways. They are used extensively as the scientific basis for environmental regulations and standards, as tools to evaluate the effectiveness of point-source pollution controls for industries, and in the assessment and remediation of contaminated sites. Provincial and territorial governments use them frequently in developing and issuing permits for discharges, and they support a variety of federal legislative acts and international conventions. By indicating changes and trends in concentrations of persistent, bioaccumulative and toxic substances in the ambient environment, the guidelines also enable resource managers to track progress toward virtual elimination of this special group of substances, and can serve as interim management objectives. Used as national recommendations rather than across the board standards, they can also be modified to take into account different resource uses and



Graphic showing how the environmental quality of our land, water and air affects different tenures and users.

environmental conditions at the local or regional level.

Most importantly, the 1999 Guidelines encourage Canadians to incorporate science into their decision making and to look at environmental conservation and protection in a more holistic manner that takes into consideration the far-ranging impacts of human activities on the environment. The document is already available in both printed format and on CD-ROM, and scientists hope it will eventually become more widely available so that all Canadians can develop science-based solutions to minimizing the impact of their day-to-day lives on the quality of our natural environment. S&E

ALL ABOUT

S&E Bulletin

SCIENCE AND THE ENVIRONMENT BULLETIN

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For more information on a subject, you can search all of the on-line resources available from Canada's four natural resource departments — including *S&E Bulletin* — by using the CanExplore search engine at [www.canexplore.gc.ca].

Media representatives and others interested in conducting further research may obtain the names and phone numbers of departmental scientists involved in these and related initiatives by contacting the *Bulletin*'s editor, Paul Hempel. He can be reached by e-mail at Paul.Hempel@ec.gc.ca, by telephone at (819) 994-7796, and by mail at Communications and Outreach Programs and Services, Environment Canada, 25th floor, 10 Wellington Street, Hull, Quebec K1A 0H3. Readers are welcome to e-mail or mail their comments and suggestions to the editor at these addresses.

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